Synopsis For Registration as Research Student

Design of Algorithms for Satellite Image Analysis

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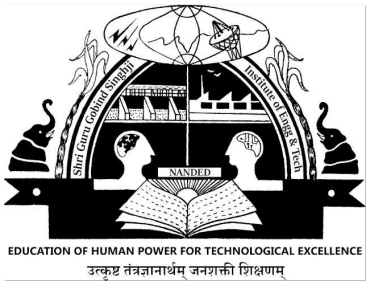
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1 Introduction and Motivation

Remote sensing is science of obtaining information about an object or feature on the earth surface without physically coming in contact with that object. These remotely collected data through various sensors may be analyzed to obtain information about the objects or features under probe. Today, remote sensing imaging is extensively used in the study of land resources, surface geology, water resources land slide study, forest study, urban development and so on at large scale.The process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.

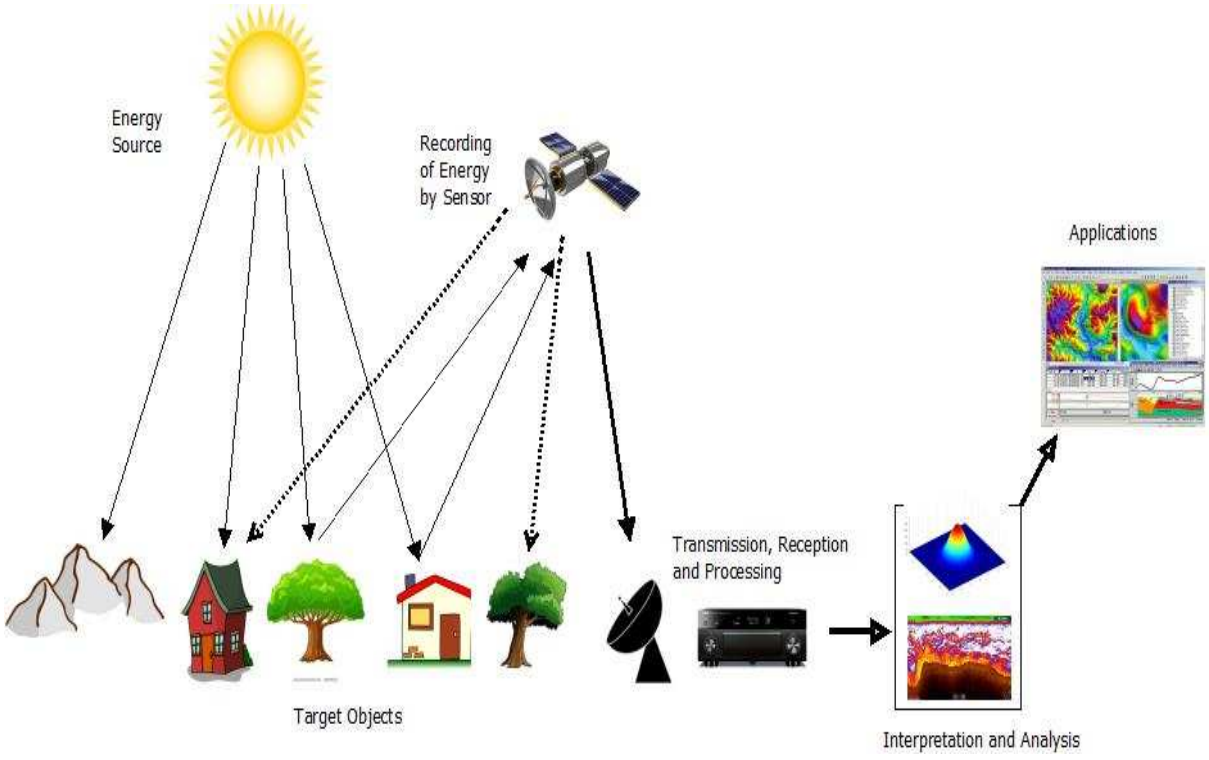

Figure 1: Remote Sensing Process

1. **Energy Source or Illumination** the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

2. **Radiation and the Atmosphere** as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

3. **Interaction with the Target** once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

4. **Recording of Energy by the Sensor** after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

5. **Transmission, Reception, and Processing** the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

6. **Interpretation and Analysis** the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.

7. **Application** the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

In general, the resolution is the minimum distance between two objects that can be distinguished in the image. Objects closer than the resolution appear as a single object in the image. However, in remote sensing the term resolution is used to represent the resolving power, which includes not only the capability to identify the presence of two objects, but also their properties. In qualitative terms resolution is the amount of details that can be observed in an image. Thus an image that shows finer details is said to be of finer resolution compared to the image that shows coarser details. When image is acquired by satellite sensors it may be distorted due to various types of errors (Geometric and Radiometric). So in-order to interpret the observations through image, pre-processing and post-processing is evident using various methods and algorithms of image processing.

Always there is a need to improve the spatial and spectral remote sensing data. In the remote sensing field, the increasing availability of spaceborne (spacecrafts and satellites) imaging sensors, operating in a variety of ground scales and spectral bands, undoubtedly provides strong motivations. Because of the trade-off imposed by the physical constraint between spatial and spectral resolutions, spatial enhancement of poor-resolution multispectral (MS) data is desirable. In a different perspective, spectral enhancement of data collected with adequate ground resolution but poor spectral selection (a single panchromatic (PAN) images) can be obtained[1].

A spectral image is a set of 2-D images (that can be seen as a 3-D cube) representing the reflectance or radiance of a scene in different parts of the electromagnetic spectrum.

This can be done either by building new satellites with high resolution power or by using image processing techniques. Building a new or making changes in existing satellite with high power is much expensive so second option is reliable and feasible. In satellite image system different sensor provide distinct data with different spatial and spectral resolution. Multispectral (MS) imaging sensor provides high spectral resolution but provide low spatial resolution and panchromatic (PAN) imaging sensor provides good spatial resolution but provide poor spectral resolution. Thus it is essential to propose methodology that can combine information from different sensors to provide information with high spectral and spatial resolution[2].

In general, merging can be can be done at three processing levels: Raw Data Level (Pixel Level), Feature Level and Description Level[3]. Merging product of panchromatic images and multispectral images simultaneously acquired for the same part of the surface is referred as Pansharpening. Combining the spatial details resolved by PAN image but with single band and several spectral bands of MS image in a merged product. Since PAN images and MS images are being acquired simultaneously by sensors which are on same platform may not require phase of spatial co-registration. Nowadays we can obtain PAN and MS images even Hyperspectral images in bundle from several earth observation satellites such as LANDSAT Series, SPOT, and Cartosat Series[4].

Image fusion is applicable in various application as a pre-processing tool which includes Agriculture, Geology, Disaster Management, Forestry, Vegetation,and so on[18]. Change detection can be defined as, the process of identifying differences in the state of an object or phenomenon by observing it at different times, in context of remote sensing[19]. Timely and accurate change detection of Earths surface features provides the foundation for better understanding relationships and interactions between human and natural phenomena to better manage and use resources. In general, change detection involves the application of multi-temporal datasets to quantitatively analyse the temporal effects of the phenomenon [20]. Change detection procedure is divided into four different steps:

1. **Identification of the change detection problem.**
2. **Selection of appropriate data.**
3. **Image pre-processing (Image Fusion).**
4. **Applying relevant change detection algorithm, including image fusion.**

Change detection to be discovered, obviously depends on the specified application, and thus influences image and band selection.

2 Literature Survey

Image fusion is widely recognized as a valuable tool for improving overall system performance in image based application areas such as defense surveillance, remote sensing, medical imaging and computer vision.

A panchromatic band is essentially a black and white band. It is one single band and typically it has a wide bandwidth of a couple of hundred nm. The wide bandwidth allows this band to have a high signal to noise, which is why panchromatic data is often available at the highest spatial resolution).Multispectral data is imagery which is captured over a series of select, narrower bands (typically 40 to 100 nm, although specifications are different on each sensor). There are a discrete and limited number of bands, generally under 10, although on some sensors it can approach 20 bands.

In context with remote sensing several methods have being proposed whose improvements in spectral and spatial resolution, by fusion of Hyperspectral (HS) images with Multispectral (MS) images and Multispectral (MS) images with Panchromatic (PAN) images by implementing various methods based on Group Spectral Embedding, Low-Rank Factorization, Morphological Operators and many version of Spectral Unmixing.[5, 6, 7]. The aim of image fusion is to integrate complementary and redundant information from multiple images to create a composite that contains a better description of the scene than any of the individual source images. This used image should increase the performance of the subsequent processing tasks. Considering the objectives of image fusion and its potential advantages, some generic requirements can be imposed on the fusion algorithm[8]: (1) it should not discard any silent information from input image. (2) it must not introduce any aircraft or inconsistencies which may mislead observation at human side and for subsequent image processing. (3) it must be tolerant to noise or misregistration.

Many algorithms have being proposed for data fusion in last decade, which include pansharpening algorithm, performance heavily depended on the spectral resampling and also on spectral region[9], algorithms based on component substitution, such as intensity-hue-saturation (HIS), principal component analysis (PCA) and based on relative spectral contribution, such as intensity modulation and Brovery transform. This simple and popular fusion methods results in spectral distorted merged product[10].

Panchromatic image modality is to cover a broad range of the wavelength spectrum, whereas an MS band covers only a narrow spectral range. Since more energy comes to panchromatic sensor, time acquisition can be reduced still preserving the same intensity response as MS images in terms of the number of photons. The advantage of the PAN image is a smaller size of pixels and, hence, better spatial resolution[11]. We may consider two definitions in [12] and [13] respectively. [12] defines image fusion as framework in which are expressed means and tools for the alliance of data originat-

ing from different sources. According to [13], fusion is the combination of pertinent (or salient) information in order to synthesize an image more informative and more suitable for visual perception or computer processing.

As discussed in [14], Brovey transform is used to combine multispectral image and highly spatial panchromatic images.The multispectral image is standardized and multiplied by the panchromatic image to include spatial subtle elements. Brovey transform is good to increase the contrast of RGB images; however it is not used when radiometry of original image is important. Brovey transform improves the spatial details of the multispectral image and it leads to color distortion when there is a long temporal change in multispectral image. The performance measurement parameters considered are: Signal to Noise Ratio, Entropy Information, Structural Similarity Index, Standard Deviation and Correlation Coefficient.

Firouz *et al.* [15] presented a image fusion method based on IHS transform, In this transformation RGB color space is converted to IHS color space. In the IHS color space Hue and Saturation represents the spectral information and Intensity represents the brightness. Intensity changes will make very small changes in spectral information and is very easy to deal. IHS transform improves both spectral and spatial information of multispectral and panchromatic image.The performance measurement parameters considered are: Root Mean Square Error,Signal to Noise Ratio, Entropy Information, Standard Deviation and Correlation Coefficient.

As proposed in [16], Image fusion based on Principal Component Analysis and High-Pass filtering, In the PCA transform arbitrary number of frequency components can be used. In this method correlated datasets can be converted to uncorrelated principal components. The first principal component (PC1) has the largest possible variance it gives more information about the panchromatic image. The high spatial resolution PAN image is histogram stretched to have the same variance as the principal component (PC1) and it replaces the PC1 component. PCA and IHS transform both provides the high spectral and spatial image at the cost of color distortion.The performance measurement parameters considered are: Root Mean Square Error and Spectral Distortion

In [17] Multisource image fusion based on wavelet transform is discussed. In the wavelet transform image fusion method the panchromatic and multispectral images are decomposed in to coefficients specific levels using discrete wavelet transform. All coefficients are combined using fusion rule and finally taking inverse wavelet transform to obtain the original image. Wavelet transform based image fusion process improves only spectral information and not spatial information.The performance measurement parameters considered are: Root Mean Square Error,Signal to Noise Ratio,and Correlation Coefficient.

Lu *et al.* [20] have reviewed various change detection algorithms which includes methods based on Algebra, Transformation, Classification, Advanced methods and GIS

based methods. In the algebra-based change detection category, image differencing is the most often used change detection method in practice. Visible red band image differencing has shown to be suitable for change detection in semi-arid and arid environments, but it is not clear that this is true in other environments such as moist tropical regions. Different authors have arrived at different conclusions about which method provided the best results among the image ratioing, vegetation index differencing, image regression, and CVA approaches, since results vary depending on the characteristics of the study areas and image data used. The background subtraction method was not often used due to its poor change detection capability [21] and [22].

The transformation category includes PCA, Gramm-Schmidt (GS), and Chi-square transformations. One advantage of these methods is in reducing data redundancy between bands and emphasizing different information in derived components. However, they cannot provide detailed change matrices and require selection of thresholds to identify changed areas. Another disadvantage is the difficulty in interpreting and labeling the change information on the transformed images [23] and [24].

As stated by [25], [26], and [27], classification category includes post-classification comparison, spectraltemporal combined analysis, Expectation Maximization (EM) algorithm, unsupervised change detection, hybrid change detection, and ANN. These methods are based on the classified images, in which the quality and quantity of training sample data are crucial to produce good quality classification results. The major advantage of these methods is the capability of providing a matrix of change information and reducing external impact from atmospheric and environmental differences between the multi-temporal images. However, selecting high-quality and sufficiently numerous training sample sets for image classification is often difficult, in particular for historical image data classification. The time consuming and difficult task of producing highly accurate classifications often leads to unsatisfactory change detection results, especially when high-quality training sample data are not available.

[28] proposed an algorithm which exploits the inherent multiscale structure of the dual-tree complex wavelet transform (DT-CWT) to individually decompose each input image into one low-pass subband and six directional high-pass subbands at each scale.

Recently [29] proposed change detection using fusion of multiple wavelet kernels. They have analyzed complementary information of two difference images followed by subtraction highlighting changes and ratio operation suppressing disturbance of complex background.

3 Problem Statement

This research is aimed towards development of novel image fusion techniques for merging high resolution panchromatic (PAN) and multispectral images (MS) data as well as its application for change detection.

3.1 Objectives

1. Development of Image fusion algorithm to generate merged product of spatially high panchromatic images and spectrally high multispectral images.
2. Development of image registration algorithm for panchromatic and multispectral images as prerequisite for change detection.
3. Developing novel change detection algorithm based on Image Fusion.
4. Identification of water bodies and burnt areas for agricultural sector.

4 Plan of Research Work

Sr. No.	Phase	Work To Be Carried Out
1	I	Literature Survey, Course Work, Identification of Strengths and Weakness of Existing Techniques for Image Fusion, Formulation of Problem Definition, Objectives and Feasibility Study.
2	II	Developing Novel Approach for Merging of Panchromatic and Multispectral Images to have product with High Spatial and Spectral Resolution Image.
3	III	Designing and Implementation of the Image Fusion System along with the Algorithms Implementation.
4	IV	Testing of the System with available database and Publication, and Thesis Writing

5 Impact on Society

Remote sensing, the technology that allows measuring objects properties from a distance, is currently undergoing tremendous advances in both precision and areas of applicability. There has being direct or indirect implication on human beings when it comes to (1) disaster management (prevention, reaction, and recovery), (2) Law enforcement, Surveillance and Security (Terror Attacks), (2) Media and commercial applications. We can continuously monitor AOI (Area of Interest) which are prone to different natural occurring disaster. We may consider, RISAT-I, which collected images

before and after cloudburst in Uttarakhand in 2013. Indian army carried out what it termed as a ”surgical strike” on terror camps located across the Line-of Control in Pakistan-occupied-Kashmir (POK), ground images for this operation were provided by the recently launched Cartosat-2C satellite. Satellite remote sensing will continue to increase in accuracy, diversity and availability, in turn increasing its impact on the human society.

6 Conclusion

Satellite image analysis using image fusion techniques is a challenging task for achieving image with high spatial and spectral resolution. Image fusion may result better option as a pre-processing tool for performing change detection. Also there is room for improvement, as the best performing system does not reach the performance for the required applications and visual interpretations. Hence, development of different techniques for image fusion, and change detection as an application have received a lot of attention from the research community and this work will add up to their efforts to increase performance in getting high spatial and spectral images from panchromatic and multispectral data.

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